SYLLABUS

OF

A COURSE OF LECTURES

ON

EXPERIMENTAL PHILOSOPHY,

DELIVERED AT

GUY'S HOSPITAL.

BY

WILLIAM ODLING, M.B., F.C.S., L.R.C.P.

LONDON:

PRINTED BY ASH & FLINT, 5, WELLINGTON STREET,
LONDON BRIDGE.

MDCCCLVI.

PART I.

GENERAL CONSIDERATIONS.

INTRODUCTION. The unity of science. The different branches of natural science. The province of *physics*, or *experimental philosophy*.

Primary conceptions of SPACE. Linear, superficial, and cubic extent. Absolute, or pure space. Infinite space. *Extension*, a finite space of three dimensions. The magnitude of an extension constitutes *bulk* or *volume*. The kind, or variety of an extension, constitutes *figure* or *form*. Bulk irrespective of figure or superficies.

Simple conceptions of *quantity* and *number*. Relations of *mathematical* science to the above abstractions, space, quantity, and number.

The idea of TIME, order, or succession.

MATTER. Different quantities of—various kinds of. The different states of aggregation.

The tenacious occupancy of space by matter, constitutes *impenetrability*; its tenacity of existence *indestructibility*. Illustrations of impenetrability, or the quality in virtue of which, no two bodies can occupy the same place at the same time. "Matter, an impenetrable extension." Impenetrability, synonymous with resistance, or repulsion. Illustrations of indestructibility.

Matter considered as it exists in *space*, and as it exists in *time*. The changes it is capable of undergoing. Distinction

between *physical* and *chemical* changes. Chemistry treats of changes in composition. Physics, of all phenomena in which the composition continues the same. No boundary line between the two sciences. Principal subdivisions of physics.

Association of chemical, physical, and abstract science, with *natural-history*. Applications of physical science to *medicine*.

Inertia. Inability of matter to effect any change in its own condition. No preference for one state of existence rather than for another. Inertia, illustrated in the phenomena of *rest* and *motion*. *Relative* and *absolute* states of rest and motion. Motion considered with regard to *direction* and *velocity*. Direction, either *rectilinear* or *curvilinear*. The direction of a rectilinear movement *constant;* that of a curvilinear movement, *perpetually varying*. Velocity *uniform*, *accelerated*, or *retarded*. A body at rest will continue for ever at rest; and a body in motion will continue for ever moving with an uniform velocity, and in a right line, unless acted upon by some external force. Objections overruled. The universality of inertia deduced from observation, not from theory. Examples of inertia.

Force. Matter possessed of *activity* as well as inertia. Simplest idea of force referrible to our own sensations. Muscular force opposed by *weight*. Muscular force opposed by *elasticity*. Weight and elasticity mutually counteracting each other. "Matter capable of exerting upon matter an effort similar to that which we appreciate by a mental impression." Matter *inert* as regards itself, *active* as regards all other bodies. Illustrations of the activity of matter.

Whatever is possessed of impenetrability or resistance, is likewise possessed of *gravitation* or *weight*. Our idea of *quantity* of matter derived from gravitation. Comparison of the gravitating and *chemical* tendencies of matter. Our idea of *kind* of matter derived from chemistry. Mutual relations of bulk, quantity, and kind of matter.

Varying relations of bulk and quantity of the same kind of matter. Balance of *repulsive* and *cohesive* action. ELASTICITY of *gases*, perfect, unlimited, alike for all. That of *liquids*, perfect, limited, special for each. That of *solids*, anomalous, manifested chiefly by changes of figure. Permanent alterations of figure or bulk. *Porosity* and *compressibility* of solid bodies. *Dilatability* of gases, liquids, and solids. Alterations in bulk from variation of condition of aggregation—from chemical action.

Questionable explanation of the variable bulk of the same identical portion of matter. Newton's view of matter. Illustrations in favour of it. Arguments against it. Question of *finite* divisibility of matter. Exact idea of an *atom*. Infinite divisibility of space. Illustrations of the extreme divisibility of matter. The *continuity* of matter. Its separability.

Transference of forces, or active states of being. Illustrations afforded by motion, heat, electricity, &c. Force, a mental abstraction. *Correlation* of forces.

PART II.

MECHANICS.

Mechanics treats of bodies in the different states of *rest* and *motion*. Mechanics proper confined to solid bodies. Respective provinces of *statics* and *dynamics*. Any of the different physical forces may produce a mechanical effect. A mechanical force is any cause whatever, which changes, or tends to change, a body's state of rest or motion.

The direction, the point of application, and the quantity of a force. A body at rest, necessarily in *equilibrium*. Transmission *of force* by solid bodies.

Statical force measured by *pressure*, expressed in weight. The term pressure inclusive of tension. Pressure, resisted motion. Direction of pressure perpendicular to surfaces pressed upon.

Velocity, when uniform, measured by the space passed over in an unit of time; when variable, by the space which would be passed over, provided the velocity were uniform during the unit.

Motive forces producing equal velocities, proportional to the quantities of matter moved. *Motive* forces acting on equal masses, proportional to the velocities generated. *Motive* forces proportional to the *momentum*, or product of the mass into the velocity. The forces of bodies in motion, proportional to their *momenta*. Illustrations of the force of moving bodies.

Pressures and *velocities* represented by lines. Compo-

sition and resolution of forces. *Resultant* of a system of forces having the same point of application. The characteristic property of the resultant is, that an equal force acting in an opposite direction will keep the body at rest. Resultant of forces acting *in the same line.* Resultant of two forces acting *angularly. Parallelogram* of forces. Examples. Comparative magnitude of resultant and components. Resultant of any number of forces, acting upon a particle. Resolution of a force into its components. Examples.

Resultant of forces having different points of application. Definitions of the *lever*, its fulcrum, and arms. Definition of the *moment* of a force. When two forces balance on a lever, their moments are equal. Principle of the lever applicable to any number of forces. With parallel forces, the *pressure on the fulcrum* is equal to the sum of the forces. Substitution of a force for the pressure of the fulcrum. Substitution of a fulcrum for any one of the forces. Couples.

Laws of Motion I. II. III. *Action and reaction* equal and contrary. Illustrated by pressure—by collision of inelastic bodies—by voluntary movements.

Uniformly accelerated motion. The *average speed* of a body moving with an uniformly accelerated velocity, is the identical speed which it has at the middle point of time. A body moving during any time with an uniformly accelerated velocity, *acquires a speed* which would carry it over *twice* the space in the same time. Uniformly accelerated motion, the result of an *uniform force* constantly acting. Similar conclusions applicable to *retarded* motion. Illustrations.

Gravitation. Masses of matter mechanically attract

one another. Illustrations principally drawn from terrestrial gravitation. Attractive force varies *directly* with the inertia of bodies, or the *quantities of matter* they contain. Hence the *direction* of terrestrial gravitation is towards the centre of the earth; and of other bodies, towards the centres of their respective masses. Nature of the plumb line. Vertical and horizontal directions. Idcal surface of the earth. Angular inclination of plummets suspended in different localities. Reciprocal movements of attracting bodies. Reaction of the earth.

Attractive force varies *inversely as the square of the distance* between the attracting bodies. Illustrated by phenomena of light. Diminution of terrestrial gravitation at considerable elevations from the earth's surface. Diminution at the equator. Distinctions between *inertia, mass, and weight.*

Various illustrations of *universal* gravitation. Mutual action of suspended cannon balls. Deviations of the plumb line. Perturbations of the planets. The Cavendish experiment

All bodies fall *with the same velocity*. Why? Illustrated by Attwoods' machine, and the guinea and feather apparatus. A body falls through sixteen feet one inch in a second.

Gravity being *continuous* in its action is an uniformly accelerating force. The spaces through which a body falls in *successive intervals* of time, are as the odd numbers. The *total* spaces through which it movcs, counted from the commencement of its fall, are as the *squares of the times. Force* with which a body falls, proportional to the time, or to the square root of the height. Retarded motion from gravity.

Motion of projectiles in parabolic curves. Affected by resistance of the air.

Centre of Gravity. The weight of an uniform horizontal rod acts as its middle point. Centre of gravity of a material line. Of a plane—of a solid. Centre of gravity not necessarily the centre of *magnitude.* The weight of a body concentrated in its centre of gravity. Centre of gravity found experimentally.

The centre of gravity of a body in equilibrium, directly above or below a fixed point of support. *Indifferent* equilibrium, when the relations of the centre of gravity and point of support are invariable. *Stable* equilibrium, when any disturbance of the position of the body is attended with an elevation of the centre of gravity. Oscillation. *Unstable* equilibrium, when any disturbance of the body is attended with a depression of the centre of gravity. Expedients for stability. Gyration. Degree of stability proportional to breadth of base, to height, to inclination—according as the *line of direction* falls within, upon, or beyond the base.

Centre of gravity not always in the mass of a body; yet has the same properties. Centre of gravity of two attached bodies. Paradoxes. Movements of the human body. Centre of inertia.

Pendulum. Cause of its movements. Isochronism. Movements independent of material or weight. Why? Effect of length. Arc or length *directly* as square of time. Gravity *inversely* as square of time. Material pendulum. Centres of oscillation and suspension. The pendulum as a measure. Metronomes.

Centrifugal Force and Motion. A consequence of

inertia. Force directly as radius—directly as weight or mass —as square of the number of revolutions. Examples. Centrifugal pumps. Effects of centrifugal force on the form of the earth. Interference with gravity at the equator.

The Simple Machines. Object of a machine, to enable a force applied at a certain point, to exert its effect at some other point. Variations in direction and intensity of applied and resulting forces. Force or power. Resistance or weight. Equilibrium of a moving body. Props, or fixed points. Paradox of machinery. Exchange of time or space for power. A machine in *equilibrium* when the moments of the power and weight are *equal*. Principle of virtual velocities.

Principle of the *Lever*. Three varieties of lever. Ratio of power to weight in. Examples of each kind. Examples in the animal frame. Effect of two props. Compound lever. Knee lever.

The *Wheel and Axle* a perpetual lever. Various modifications of. Toothed wheels.

The *Pulley*. Single moveable pulley. Three systems of pulleys.

Principle of the *Inclined Plane*. Illustrations of. Inclined roads. Falling bodies.

The *Wedge* an inclined plane. Theory inapplicable. Experimental proof. Applications.

The *Screw* an inclined plane. Addition of lever. Immense force of the screw. The differential screw. The micrometer screw.

PART III.

HYDROSTATICS AND PNEUMATICS.

Elastic and non-elastic fluids ? Comparison of the modes in which *solids* and *fluids* transmit pressure. Fluids transmit pressure equally in every direction. The direction of the pressure perpendicular to the surfaces pressed upon. The hydrostatic paradox compared to a lever. The hydrostatic bellows. Bramah's press. Fluid pressure as a telegraph.

Pressure of a liquid due to its *weight*. Proportional to the area of the surface pressed upon, and to the *height* of the liquid above that surface. Irrespective of the amount of liquid. Acts equally in every direction. Illustrated by a spring. Experimental manifestations of upward, downward, and lateral pressure. Calculation of the *total pressure* upon a surface. Bursting of vessels by hydrostatic pressure. Pressure on flood-gates.

Liquids maintain their *level*. Parodoxical illustrations. Comparative pressures produced by different liquids, proportional to their densities. The pressure of a column of water one foot high, upon a square foot of surface, equal to 62.32 pounds. Physiological relations of liquid pressure.

On the *gaseous* state. Illustrations of the impenetrability, inertia, and elasticity of air. Law of Boyle or Mariotte. The *volume inversely*, the elasticity directly as the pressure. The air pump. Different forms of construction. The condensing syringe. The air gun. The compressed-air fountain. Hero's fountain.

Process of weighing gases. Discovery of the *weight of the air*. Observations of Galileo, Torricelli, and Pascal. The barometer, its construction, varieties, and applications. The *pressure of the atmosphere* equal to fifteen pounds on the square inch. Acts equally in every direction. Illustrations of upward and lateral pressure. Why bodies are not crushed. Experimental illustrations of the *balance* between elasticity and weight.

Correction of gases for pressure. The pressure guage. Density of the successive strata of the atmosphere decreases in *geometrical* progression. Mode of measuring heights by the barometer. Limit to the atmosphere? Physiological relations of gaseous pressure.

Effects of submersion. Principle of Archimedes. An immersed body displaces its own *volume* of liquid, and is pressed upwards by the *weight* of that liquid acting at its centre of gravity. Explanation and experimental proof. Apparent, not real loss of weight. Condition of sinking or floating. A floating body displaces *its own weight* of liquid, and is pressed upwards by the *weight* of that liquid acting at its centre of gravity. Condition of stable equilibrium of a floating body. Properties of the *metacentre*. Expedients to effect stability. Buoyancy of human body. Effect of working under water. Any material may float. Archimedean principle applicable to gases. Aerostation.

The intermittent fountain. The syphon. Its various modifications. The lifting pump. The suction pump. The forcing pump. The fire engine.

Momentum of a liquid escaping from an orifice proportional to the pressure. The momentum equals the product

of the area of the orifice, into the square of the velocity with which the liquid passes the orifice. Pressure proportional to *depth*—proportional to the *square of the velocity*. Torricelli's theorem. Perpendicular and lateral jets. Means for obtaining an *uniform* efflux. Phenomena of the contracted vein. Effect of an ajutage. Reaction of escaping liquid. Turbines. Lateral pressure and friction of liquids in motion. Consequent phenomena of suction. The resistance of a liquid to the movement of a solid body through it, increases with the square of the velocity. The Archimedian screw. The water ram.

Efflux of gases. Lateral pressure of gases in motion. Reaction of an escaping gas.

(The other five Parts will follow.)